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Full Length Article

Understanding ash deposition for Zhundong coal combustion in 330 MW utility boiler: Focusing on surface temperature effects

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A B S T R A C T

Zhundong coal as a high quality steam coal has not been widely utilized due to severe fouling and slagging problems during combustion. It is crucial to reveal the slagging and fouling mechanisms in a boiler burning Zhundong coal. In this paper, the properties of ash deposits collected from various heat transfer surfaces in a 330 MW boiler were characterized by ICP-OES, SEM – EDX, and XRD. These results were also verified by an experiment burning Zhundong coal in a drop-tube furnace and thermodynamic calculation by the software FactSage. The results indicated the ash deposited on different heat transfer surfaces in 330 MW boiler burning Zhundong coal could be classified into silicates and sulfates based on their elemental and mineral analysis. Further, the ash deposited on the division panel superheater is obviously divided into three layers. In the first layer, wollastonite and sodium silicate are the main minerals with the contents of quartz and feldspar being relatively small. The types of mineral in the second layer are the same with the first layer, but their contents are different from the first layer. Meanwhile, the amount of crystalline phase in the third layer is lower than that of the first and second layer. In addition, the temperature of the flue gas or the tube played an important role in the mechanism of ash deposition. Thermodynamics calculation also shows $CaSO_4$ can be formed at all temperatures and there only exists $CaSiO_3$ formed in the range 900–1200 °C. The ash deposits along the flue gas flow attributes to sulfates, silicates and sulfates, respectively. The result of the thermodynamic calculation is in accordance with the experiment results obtained in the drop-tube furnace.

1. Introduction

Zhundong coal field in Xinjiang province is currently the largest coalfield in China and the reserve for this coal is estimated to be 390 billion tons [1–3]. Zhundong coal is considered as a high quality steam coal due to its low-to-medium ash yields, low phosphorus and sulphur contents, high volatile matters, and high calorific value [4]. However, severe slagging and fouling occur during the combustion of Zhundong coal. The mechanisms for slagging and fouling are different. Slagging mainly takes place in the radiant heat transfer section in the boiler, while fouling occurs in the convective heat transfer section of the boiler. In addition, slagging is caused by the molten ash particles while fouling results from the behaviour of various components in the fly ash as the flue gas cools down. These components include silicate liquids, and sulfates formed from the reaction between sulphur oxides and alkali components [5].The ash deposit layer on heat transfer surfaces cannot be easily removed by traditional soot blowing techniques [6–8].

It has been widely accepted that temperature, coal ash composition and particle size are three main factors that have strong influences on the formation of ash deposits. The ash deposition is affected by wall temperature and furnace gas exit temperature. Slagging occurs at wall temperature above 882 °C while fouling occurs during the condensation of gaseous species such as NaCl or $CaSO_4$ to form a sticky coating layer on cooled surfaces [9]. Typically, glassy and easily molten deposits form on high temperature surfaces while porous and sintered (not molten) deposits form on low temperature surfaces [10]. Additionally, higher furnace gas exit temperatures can make some minerals in fly ash reach a molten state, causing severe slagging problems in the boiler [11].

While previous studies show the importance of temperature on ash deposition, presumably through the chemical reactions of different ash components. Wu et al. [12] demonstrated that the formation of NaCl, or Na_2SO_4 can cause a high fouling propensity. According to Tang et al. [13], Ca and S are the main components of combustion residues and play an important role in the ash deposition process on convective heat transfer sections through the formation of anhydrite. Song et al. [14] also indicated that a compound salt $CaSO_4$-Na_2SO_4 formed burning coal can be considered as an important cause of ash deposition. Wei et al.

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Nomenclature

$T_{flue\ gas}$	temperatures of flue gas, °C
T_{wall}	temperatures of the tube, °C
wt	the weight percentages of elements, %
B/A	the base/acid ratio
f	fouling index, %
R-WW	rear water wall
D-PS	division panel superheater
R-PS	rear panel superheater
R-PR	rear panel reheater
FR	final reheater
FS	final superheater
PS	primary superheater

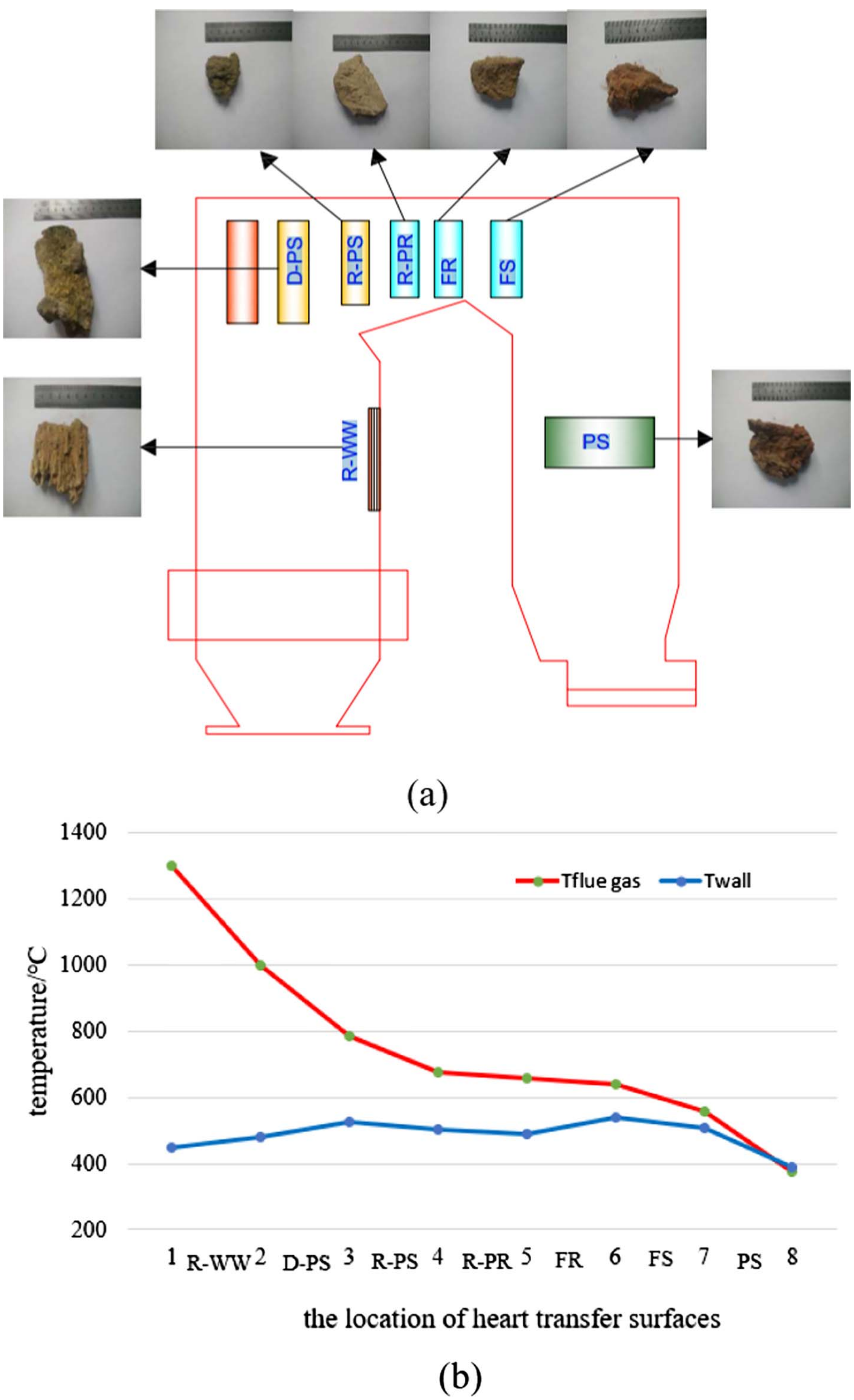

Fig. 1. The schematic for the 330 MW boiler (a) the sampling positions in the boiler, (b) temperature distributions of flue-gas and heat transfer surfaces.